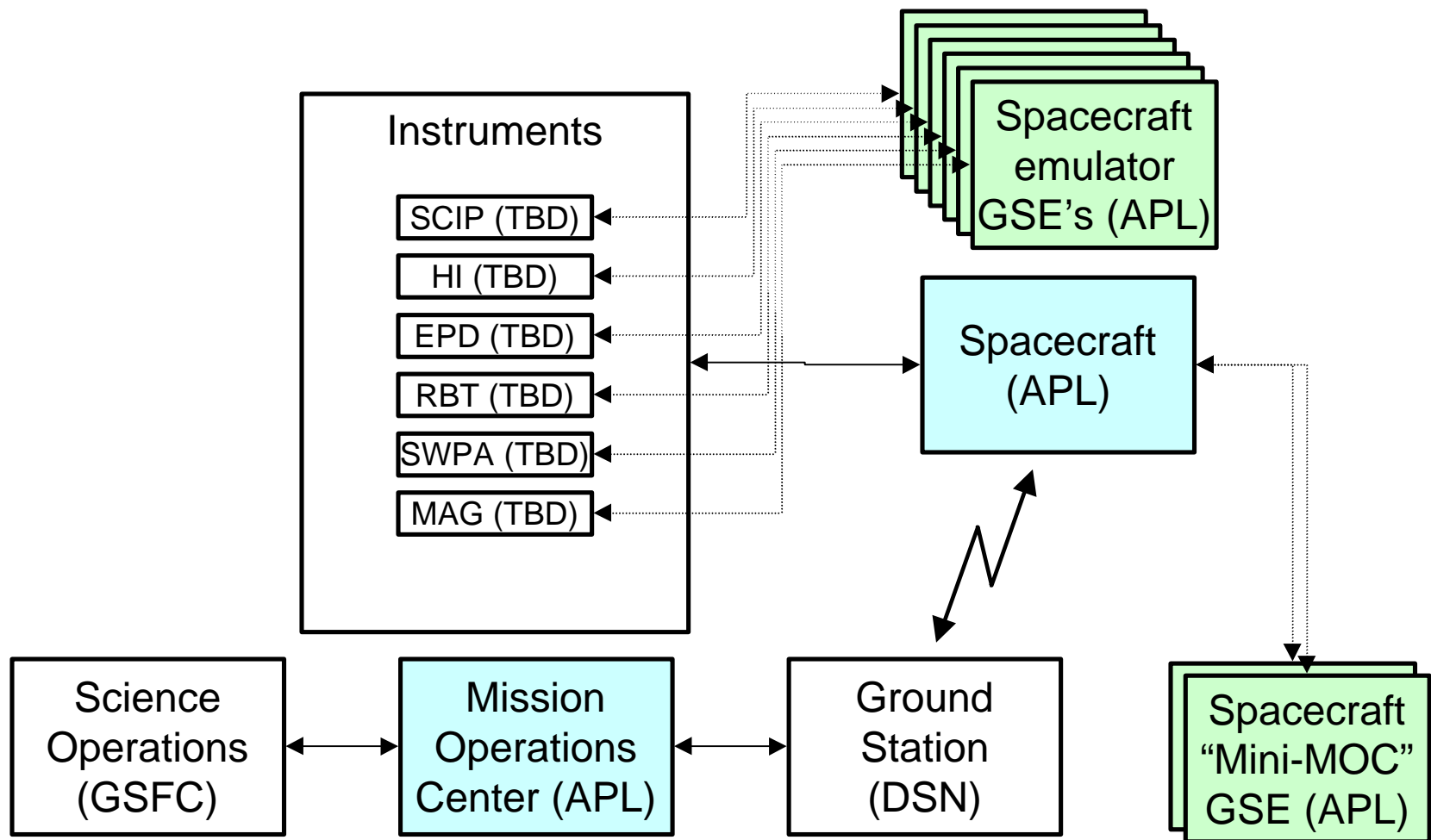


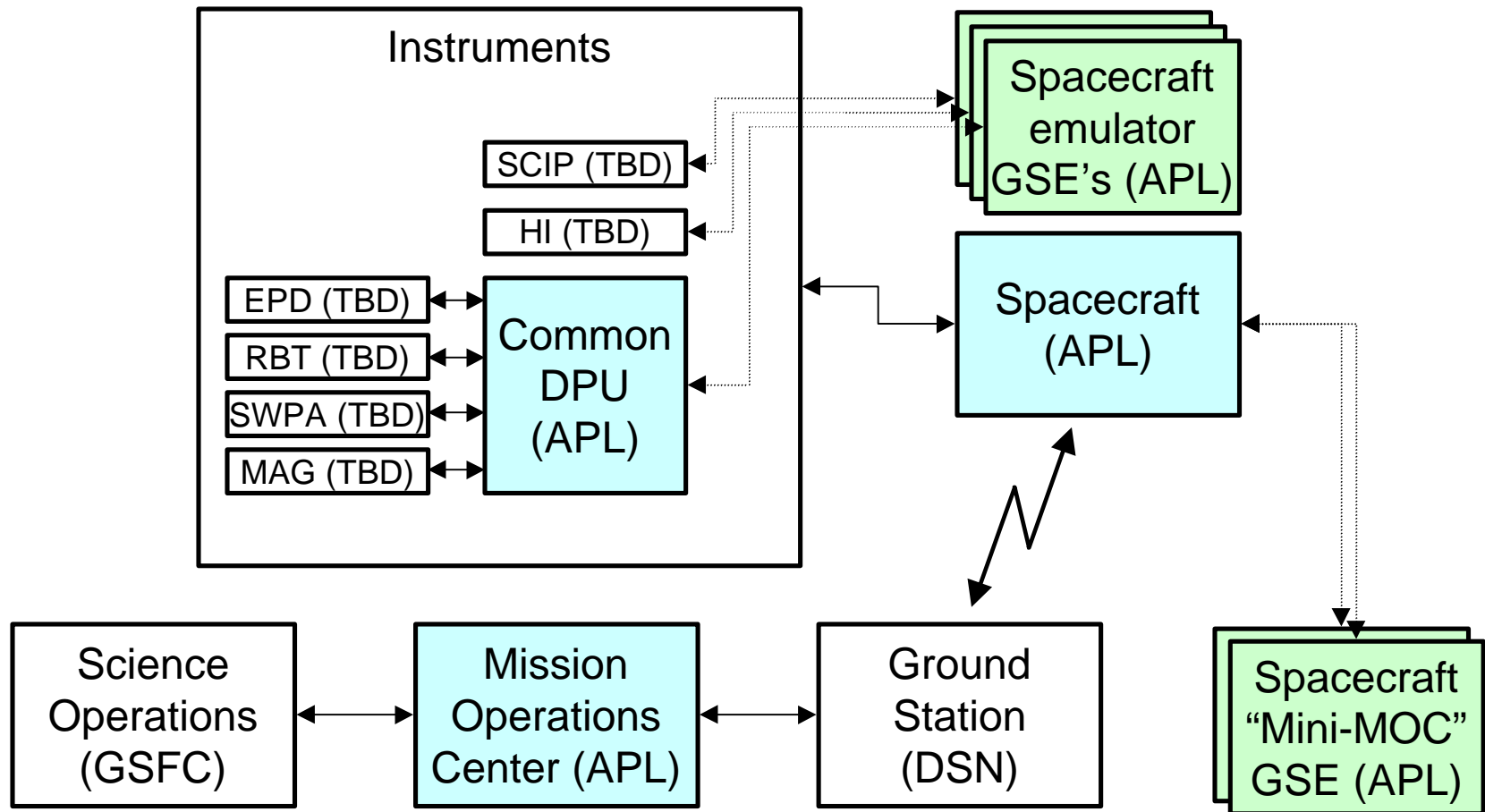
# STEREO Software

Ben Ballard

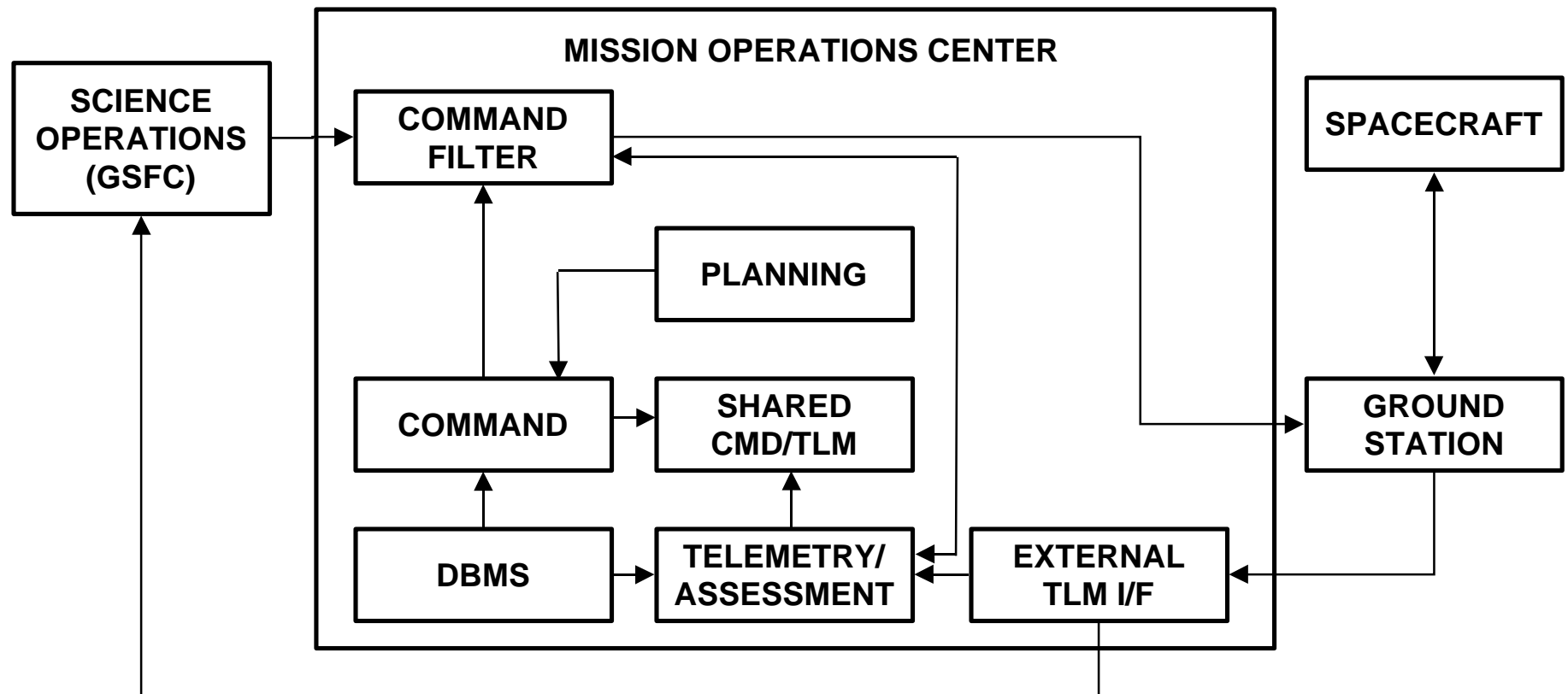
# STEREO Software “Sub”system



# Alternate System Configuration



# Mission Operations Software



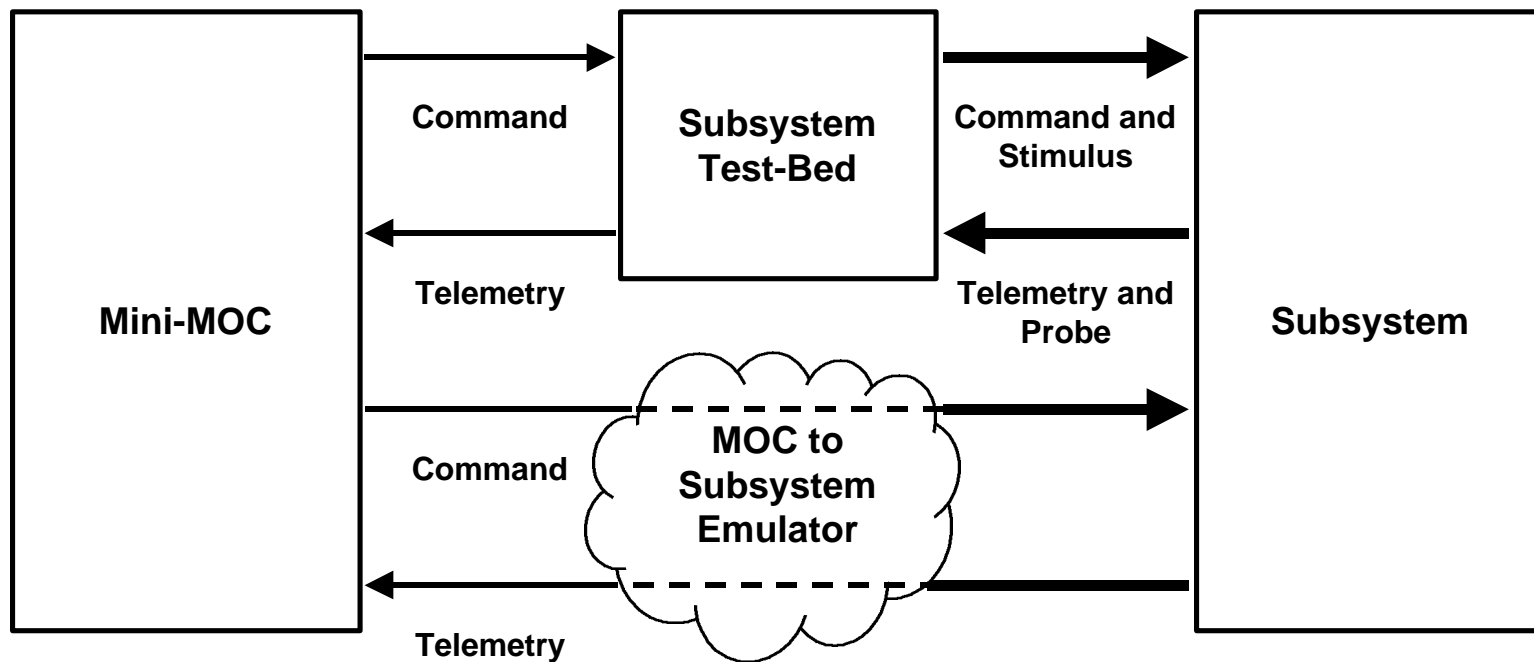
# Mission Operations Functions

- Functions:
  - Support Interface with Science Operations (GSFC)
    - Receive instrument command loads
    - Distribute instrument science data
  - Maintain Spacecraft command and telemetry dictionaries
  - Support Spacecraft activity planning
  - Uplink all commands to spacecraft via ground station
  - Receive all downlink from ground station
  - Assess and archive spacecraft telemetry data
- TIMED Implementation
  - Based on EPOCH 2000 COTS product, with APL customization

# Mini-MOC Functions

- The Mini-MOC will support 2 subsystems: C&DH, and G&C
- The Mini-MOC
  - is a stripped-down version of the MOC, available early in the program, for use in subsystem testing.
  - can send both GSE (Ground Support Equipment) and spacecraft subsystem commands.
  - can receive, decommutate, display, alarm, and archive both GSE and spacecraft subsystem telemetry.
  - uses the same command and telemetry dictionaries, command procedures, and display pages as the MOC.

# Mini-MOC Configuration



**Key:**

**TCP/IP socket over ethernet**

**Hard-wired**

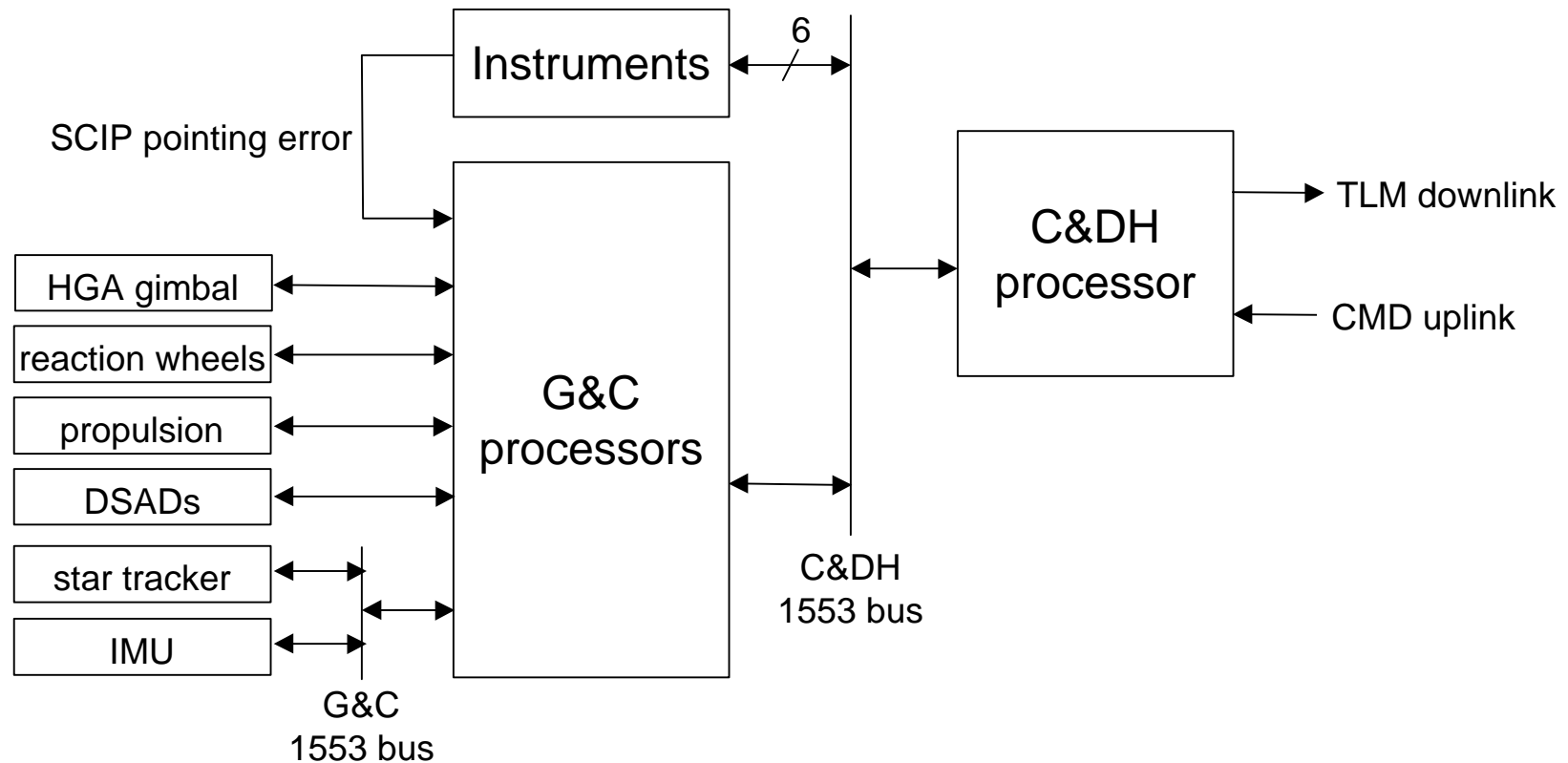
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# Spacecraft Emulator

- A tool for use of instrument developers to verify interfaces with spacecraft
- PC-based emulator, with:
  - 1553 interface with driver implementing spacecraft bus schedule
  - software allowing command transmission to instrument, telemetry reception, monitoring, display, etc.
- TIMED provided one emulator to each instrument developer

# Flight Software Environment



# C & DH Differences From TIMED

- Single string processor implementation
- 7 instruments instead of 4
- High speed RS-422 serial interface for SCIP
- Max. total science collection rate ~410 kbps. instead of 55 kbps.
- Max. downlink rate 200-800 kbps. (TBD) instead of 4 Mbps.
- Collection and downlink of broadcast data

# C&DH Requirements - 1

- Support science data collection
  - Allow instruments to generate their max data rate simultaneously
    - SCIP - 400 kbps
    - HI - 7 kbps
    - EPD - 0.2 kbps
    - Mag - 0.2 kbps
    - RBT - 0.2 kbps
    - SWPA - 0.2 kbps
  - Allow variable instrument bandwidth allocation
  - Support a real-time science downlink capability
  - Label science and attitude history packets so they can be identified and routed to GSFC without inspection

# C&DH Requirements - 2

- Support 8 Gbit recorder w/simultaneous record, playback
  - dump entire recorder in 3 hours...
  - while continuing to record new data from science instruments at their maximum rates
- Support CCSDS-compatible uplink/downlink
- Support 500 bits/sec. “broadcast” telemetry mode
- Maintain and distribute time to 0.1 sec accuracy
- Allow for software upgrade capability
- No C&DH data compression is required

# C&DH Software Baseline

- TIMED architecture
  - reuse requirements document as starting point
  - 12 MHz. Mongoose running Nucleus+ RTOS
  - same approach to uplink, downlink, 1553 bus management
  - add drivers for RS-422 high speed link
  - delete instrument daily packet quota enforcement
  - power management requirements?
- Load estimates:
  - CPU usage: 25% (based on TIMED estimates updated for STEREO)
  - Memory: TIMED is under 30% usage of code space (RAM and flash), assuming 50% of memory is available for code

# C&DH Loading Estimate - 1

## STEREO C&DH Load Estimates

Original from Steve Williams' TIMED CDR info. *Italics indicate changes from TIMED estimates*

Software Module	Exec Freq (Hz.)	msec per exec	msec per sec	Assumptions
<b>Command Processing</b>				
<i>Command Buffer Ready ISR</i>	<i>2</i>	<i>0.1</i>	<i>0.2</i>	<i>~ 2 times / sec. with continuous 100 bps uplink</i>
<i>Perform Coding Layer Checks</i>	<i>2</i>	<i>0.1</i>	<i>0.2</i>	<i>Will occur after a Command Buffer Ready ISR</i>
Perform Transfer Layer Checks	1	0.2	0.2	Assumes 1 transfer frame received per sec.
Perform Segmentation Layer Checks	1	0.2	0.2	Executes after Transfer Layer Checks
Perform Packetization Layer Checks	1	0.2	0.2	Assumes 1 CMD packet assembled per sec.
Check for Command Packet Timeout	1	0.15	0.15	
Check C & DH Commands	1	1	1	Assumes CMD packet contains C & DH commands
Execute C & DH Commands	9	0.2	1.8	Assumes execution of 9 relay commands per sec.
Relay Command Complete ISR	9	0.1	0.9	Can execute no more than 9 relay commands / sec.
<i>Input Code Block</i>	<i>2</i>	<i>0.15</i>	<i>0.3</i>	
<b>1553 Bus Management</b>				
<i>Build 1553 Minor Frames</i>	<i>16</i>	<i>2</i>	<i>32</i>	<i>Double TIMED loading for more instruments</i>
<i>Process 1553 Minor Frame Results</i>	<i>16</i>	<i>2</i>	<i>32</i>	<i>Double TIMED loading for more instruments</i>
<b>PCI Bus Management</b>				
"TIMED" PCI Transaction Complete ISR	50	0.1	5	Assumes 50 "TIMED" PCI transactions per second
<i>SCIP PCI Transaction Complete ISR</i>	<i>15</i>	<i>0.1</i>	<i>1.5</i>	<i>15 blocks, 2000 16-bit words each = 480000 bps</i>
<i>Manage GNS Interface</i>	<i>0</i>	<i>0.2</i>	<i>0</i>	<i>GNS eliminated in STEREO</i>
<b>C&amp;DH Data Management</b>				
Input Housekeeping Data	1	0.1	0.1	
Form C & DH Telemetry Packets	1	1.2	1.2	
Form Housekeeping Telemetry Packets	1	1	1	
Update Data Summary Table	1	0.5	0.5	
<b>Battery Management</b>				
Perform Peak Power Tracking	16	0.3	4.8	
Perform Coulometry	16	0.15	2.4	

# C&DH Loading Estimate - 2

## STEREO C&DH Load Estimates

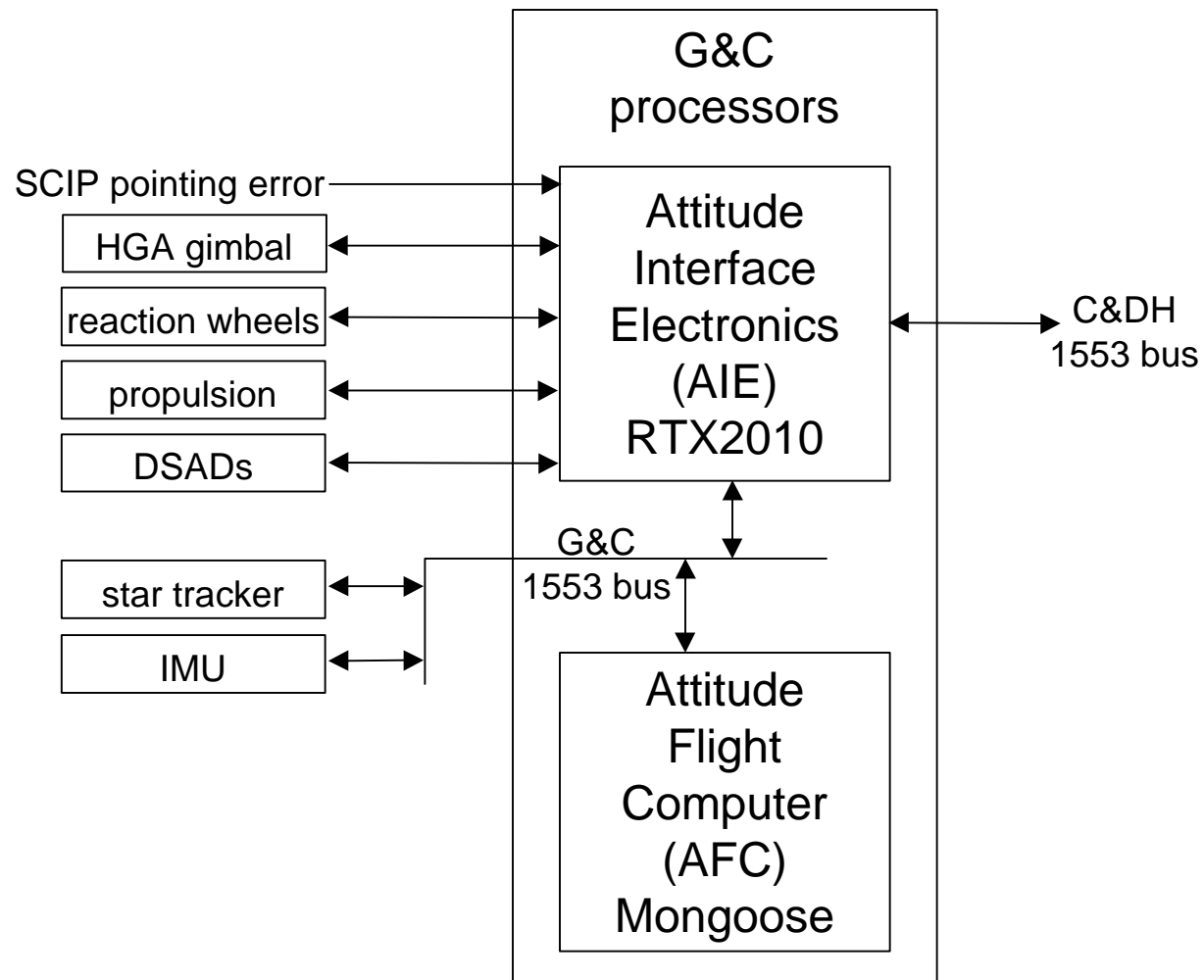
Original from Steve Williams' TIMED CDR info. *Italics indicate changes from TIMED estimates*

Software Module	Exec Freq (Hz.)	msec per exec	msec per sec	Assumptions
<b>Autonomy Processing</b>				
Evaluate Arithmetic Functions	1	6.4	6.4	Assumes 100 usec. for each of 64 floating point computations and comparisons
Evaluate Autonomy Rules	1	51.2	51.2	Assumes 100 usec. to evaluate each of 512 rules
Evaluate Time-tagged Rules	1	25.6	25.6	Assumes 50 usec. to evaluate each of 512 rules
<b>SSR / Downlink Management</b>				
<i>Parse Telemetry Packets</i>	<i>64</i>	<i>0.25</i>	<i>16</i>	<i>TIMED packet generation rate multiplied by 8</i>
<i>Manage SSR Recording</i>	<i>64</i>	<i>0.25</i>	<i>16</i>	<i>TIMED SSR recording multiplied by 8</i>
Start SSR Playback	1	0.2	0.2	
Continue SSR Playback	1	0.2	0.2	
Check SSR Memory	16	1	16	
SSR ISR	1	0.1	0.1	Normally 1 every 60 seconds during SSR playbacks
<i>Manage Real-time Downlink</i>	<i>2</i>	<i>0.25</i>	<i>0.5</i>	<i>TIMED real-time downlink rate divided by 5</i>
<i>Manage "Broadcast" Downlink</i>	<i>1</i>	<i>0.25</i>	<i>0.25</i>	<i>New requirement for STEREO</i>
<b>System Functions</b>				
1 PPS ISR	1	0.2	0.2	
1 Hz Timer ISR	0	0.1	0	Not be executed in normal operation
16 Hz Timer ISR	15	0.1	1.5	
Power System Timer	16	0.1	1.6	
Interrupt Latencies - Timer 0	100	0.1	10	100 interrupts per second, @ 100 usec. response
<i>Interrupt Latencies - user interrupts</i>	<i>150</i>	<i>0.04</i>	<i>6</i>	<i>125 interrupts per second, @ 40 usec. response</i>
<i>Context Switching</i>	<i>125</i>	<i>0.04</i>	<i>5</i>	<i>100 context switches, @ 40 usec. per switch</i>
Correctable Error ISR	0	0.1	0	Not normally executed
Scrub C & DH Memory	16	0.4	6.4	
<b>Total Estimated C&amp;DH Loading</b>	<b>24.9%</b>			

# G&C Requirements

- “Just like TIMED, except” -
  - Single string processor implementation
  - Simpler safe modes and transitions
  - No torque rods
  - Propulsion system added
  - High gain antenna gimbal added
  - Other system components not yet selected
  - SCIP has tight pointing, jitter, and knowledge requirements
    - SCIP provides pointing error signal to G&C system
    - RBT antennas will make spacecraft mechanically flexible
    - Control loop processing requirements TBD
- I.e., G&C requirements are not necessarily very similar to TIMED, and are not yet well known

# G&C Processor Baseline (TIMED)



# G & C Software Baseline

- TIMED software architecture
  - 12 MHz. Mongoose running Nucleus+ RTOS, with RTX2010 based Attitude Interface Electronics
  - Reuse requirements documents as starting point
  - Reduce or eliminate attitude processing in AIE
  - Use RTW again to automatically generate attitude “c” code for AFC
- Load estimates:
  - CPU usage: AIU usage about 25%; AFC unmeasured
  - Memory: TIMED AIU uses over 85% of RAM; AFC uses <30% of RAM allocated for code

# TIMED Memory Estimates

	EE/Flash (Kbytes)				RAM (Kbytes)		
C&DH	Usage	Used	% used		Usage	Used	% used
	Boot segment:180Kbytes actually used of 256K	256	6.3%		OS, code, large buffers, variables, constants, etc.	300	14.6%
	OS, code (2 copies)	600	14.6%		command macros	512	25.0%
	cmd macros (2 copies)	1024	25.0%		autonomy and time-tagged rules	256	12.5%
	autonomy rules (2 copies)	512	12.5%		Total used	1,068	52.1%
	Total used	2392	58.4%		Total available	2,048	100.0%
	Total available	4096	100.0%				
AFC	Usage	Used	% used		Usage	Used	%used
	Boot segment:180Kbytes actually used of 256K	256	6.3%		OS, code (with RTW)	300	14.6%
	Parameters	512	12.5%		initialized data	40	2.0%
	OS, code (with RTW)	512	12.5%		uninitialized data	200	9.8%
	Total used	1280	31.3%		Total used	540	26.4%
	Total available	4096	100.0%		Total available	2048	100.0%
AIU	Usage	Used	% used		Usage	Used	%used
	Code	81	63.3%		Page 0	53	41.4%
	Parameter blocks	4	3.1%		Page 1	57	44.5%
	Total used	85	66.4%		Total used	110	85.9%
	Total available	128	100.0%		Total available	128	100.0%

# Trade Studies for Phase A/B - 1

- Simplified architecture for G&C processor(s)
  - + possibly replace both processors with one
  - + reduce total software effort
  - + use “modern” development environments
  - debug “modern” development environments (again...)?
  - it seems the “ultimate” rad-hard flight processor is always “right around the corner, but not quite in time for this project....”

# Trade Studies for Phase A/B - 2

- Variable length packets
  - Eliminate hardware dependencies on fixed length packets so it won't be too late if study favors variable length packets
  - Study whether benefits of variable length packets outweigh costs
    - TIMED Mission Ops people would have preferred variable length (EPOCH 2000 fully supports variable packet sizes)
    - Fixed length restriction was a problem for TIMED experimenters (especially difficult for TIDI)
- Selective SSR Playback to allow direct replay of missed transfer frames without playing back a whole segment
- Operating systems, tools
  - Nucleus+ (TIMED RTOS for Mongoose), VxWorks, VRTX
  - TASKING (TIMED development tools for Mongoose), gnu

# Technology Insertion Candidates

- Use of commercially available file system extensions to Real Time Operating System
  - Proposal being submitted to NASA for additional funding
  - Code and parameter upload and download operations become simple file transfers
  - Easy, familiar model for Mission Operations
  - File volumes in RAM, EEPROM/flash, and on the SSR can provide convenient local volatile and non-volatile onboard storage
- Variable length packet uses
  - flexible telemetry updates
  - more efficient use of downlink bandwidth (instrument and spacecraft)

# Software Cost Drivers

- Development of end-to-end architecture before implementation begins, including requirements of:
  - Experimenters and Mission Data Center (via GSFC interface)
  - Mission Operations
  - Integration and Test
  - Flight Hardware
  - Flight Software
- Collocation of software developers with hardware designers
- “Zero-based” requirements to reduce testing costs
- Software reuse (architecture, designs, staff experience, code, test procedures) allowed by various configurations